Optimization of a Gravitational Wave Detection Pipeline

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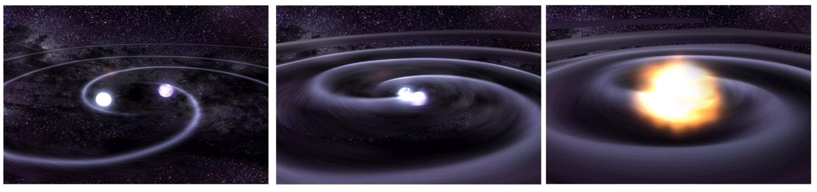
THE UNIVERSITY OF WESTERN AUSTRALIA

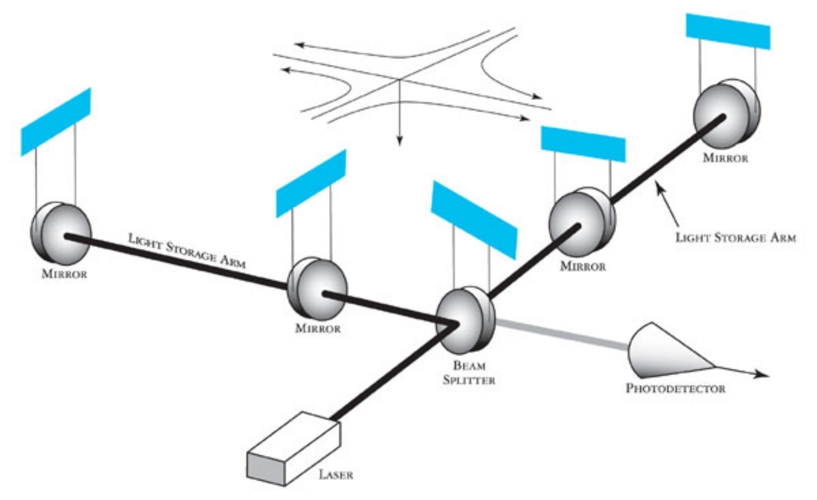
Structure

N-detector

Gravitational Waves



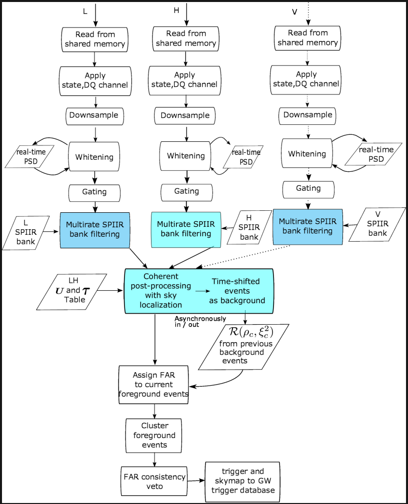
Detectors



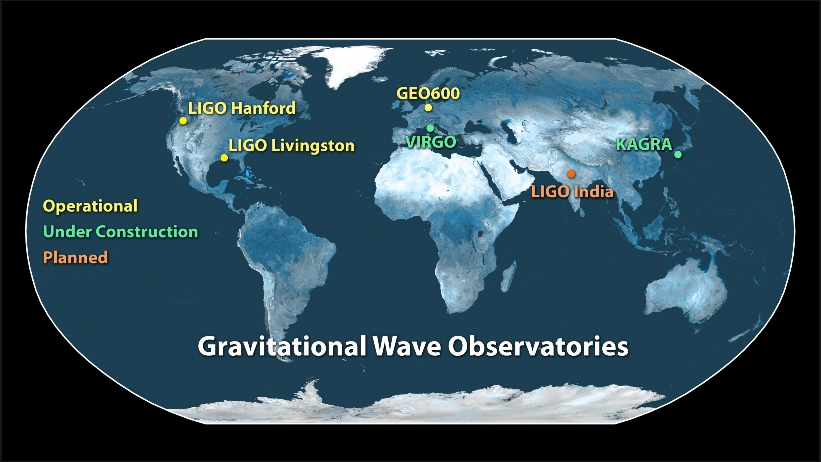
Mirror
Light Storage Arm
Mirror
Mirror
Light Storage Arm
Mirror
Beam
Splitter
Photodetector
Laser

Processing Pipelines

The SPIIR Pipeline



The SPIIR Pipeline



Internal datastructures

```
#define MAX_IFO_COMBOS 7 // 2^3-1
static const IFOType IFOComboMap[MAX_IFO_COMBOS] = {
    {"H1", 0},
    {"L1", 1},
    {"V1", 2},
    {"H1L1", 3},
    {"H1V1", 4},
    {"L1V1", 5},
    {"H1L1V1", 6},
};
```

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    {"V1", 2},
    {"K1", 3},
    {"H1L1", 4},
    {"H1V1", 5},
    {"H1K1", 6},
    {"L1V1", 7},
    {"L1H1", 8},
    {"V1H1", 9},
    {"H1L1V1", 10},
    {"H1L1K1", 11},
    {"H1V1K1", 12},
    {"L1V1K1", 13},
    {"H1L1V1K1", 14},
};
```

Internal datastructures

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    {"V1", 2},
    {"H1L1", 3},
    {"H1V1", 4},
    {"L1V1", 5},
    {"H1L1V1", 6},
};
```

The power of powers of 2

0 0 0 0 0

The power of powers of 2

0 0 0 0 1

The power of powers of 2

0 0 1 0 1

The power of powers of 2

1 0 1 0 1

The power of powers of 2

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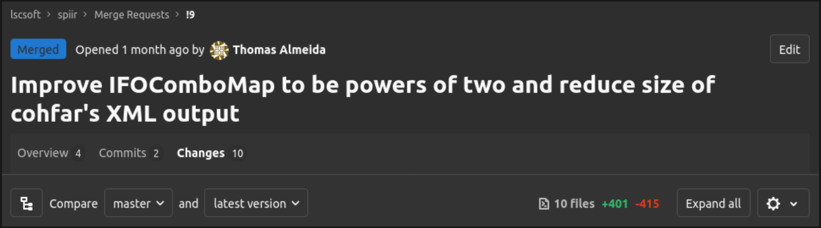
    { "V1K1", 11 },
    { "H1V1K1", 12 },
    { "L1V1K1", 13 },
    { "H1L1V1K1", 14 },
};
```

The power of powers of 2

$$N_{detectors} = \texttt{popcount(icombo)}$$

Detector being used: $\texttt{icombo \& } 2^{ifo}$

The power of powers of 2



The hunt for hardcoded detectors

```
typedef struct tagPostcohInspiralTable {
    struct tagPostcohInspiralTable *next;
    long process_id;
    long event_id;
    LIGOTimeGPS end_time;
    LIGOTimeGPS end_time_H;
    LIGOTimeGPS end_time_L;
    LIGOTimeGPS end_time_V;
```

The hunt for hardcoded detectors

```c
typedef struct tagPostcohInspiralTable {
    struct tagPostcohInspiralTable *next;
    long process_id;
    long event_id;
    LIGOTimeGPS end_time;
    LIGOTimeGPS end_time_sngl[MAX_NIFO];
```

The hunt for hardcoded detectors

Complexity analysis

Complexity Analysis

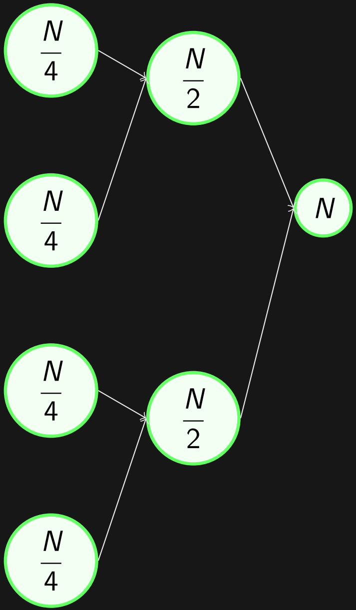
Asymptotic growth rates

- compare algorithms
- compare with inherent performance barriers
- provide simple closed form approximations
- big O — upper bounds on growth
- big Ω — lower bounds on growth

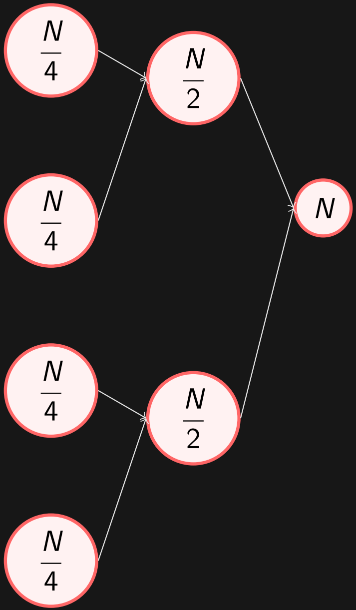
Analysis of recursive programs

- express as recurrence relation
- look for pattern to find closed form
- can then do asymptotic analysis

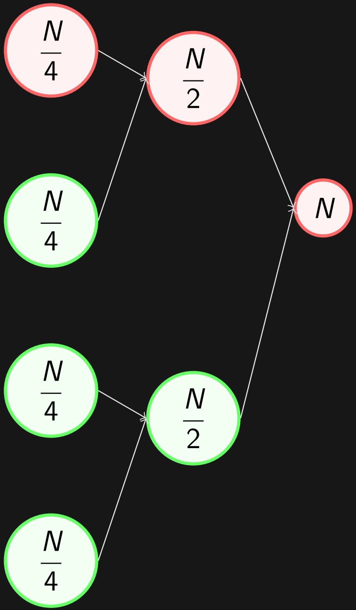
Complexity Analysis



Work



Span

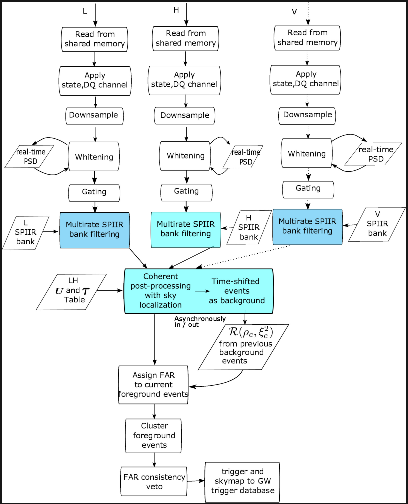


Parallel definitions

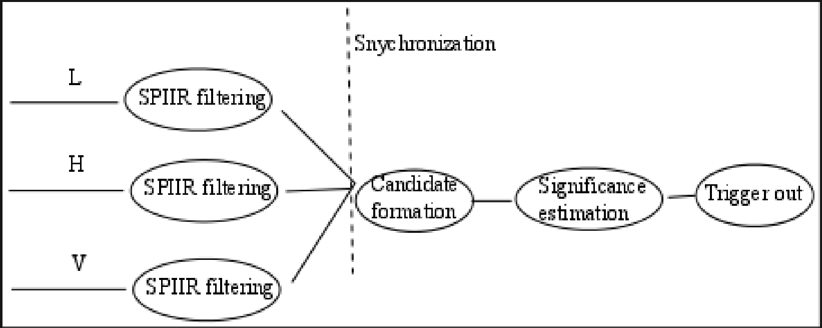
- Work $= T_1$
- Span $= T_\infty$
- Brent's Theorem
  $O(\frac{T_1}{P} + T_N)$

So why do we care about this complexity analysis?

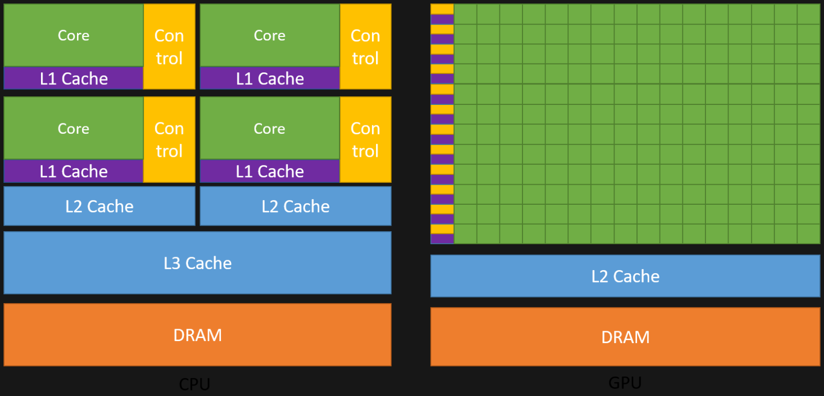
Why do we care?



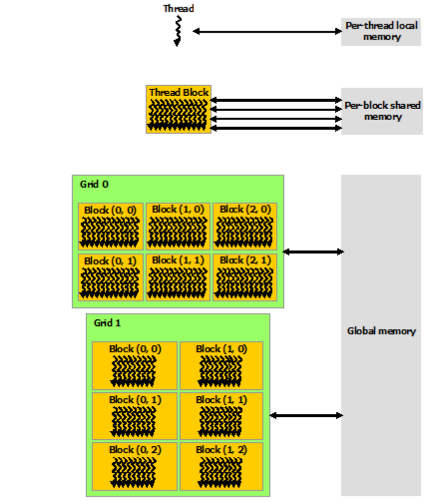
Why do we care?



CUDA


Core
Con
trol
L1 Cache
Core
Con
trol
L1 Cache
Core
Con
trol
L1 Cache
Core
Con
trol
L1 Cache
L2 Cache
L2 Cache
L3 Cache
DRAM
CPU
L2 Cache
DRAM
GPU

Compute model



Callgraph generation

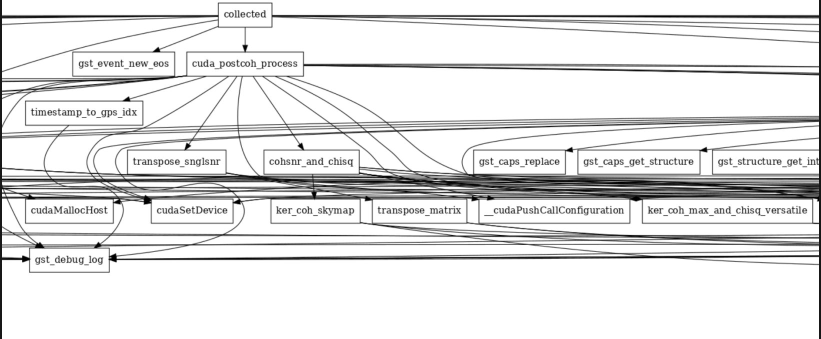
```
tommoa:~/Documents/research# [master] python3 -m utils --help
usage: utils [-h] {combine,co,iir,dot,pipeline} ...

Utilities to help with Tom Almeida's GENG5551 research.

optional arguments:
  -h, --help            show this help message and exit

subcommands:
  {combine,co,iir,dot,pipeline}
                        subcommand help
tommoa:~/Documents/research# [master]
```

Callgraph


collected
gst_event_new_eos
cuda_postcoh_process
timestamp_to_gps_idx
transpose_snglsnr
cohsnr_and_chisq
gst_caps_replace
gst_caps_get_structure
gst_structure_get_int
cudaMallocHost
cudaSetDevice
ker_coh_skymap
transpose_matrix
__cudaPushCallConfiguration
ker_coh_max_and_chisq_versatile
gst_debug_log

Analysis

$$
\begin{aligned}
T_\infty &= O(NT + N^2 + D^3 + D^2 \log N + D \log S + D \log P), \\
T_1 &= O(NT + N^2 + SPD^3 + SPBD^3 + ND^2),
\end{aligned}
$$

where D is the number of detectors,
S is the number of sky directions,
T is the number of templates,
N is the number of samples,
B is the number of time shifts made to background noise;
and $P = \max\{S, T\}$.

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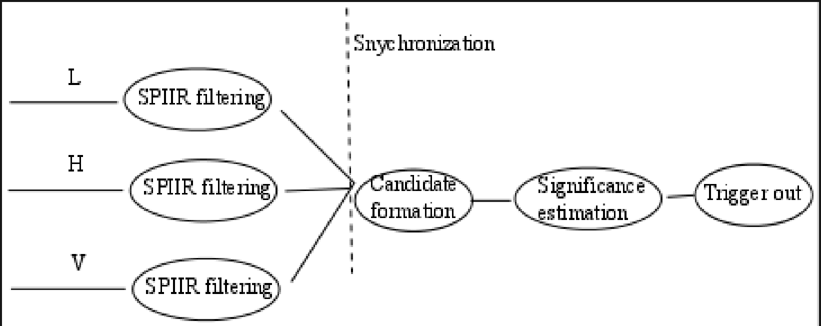
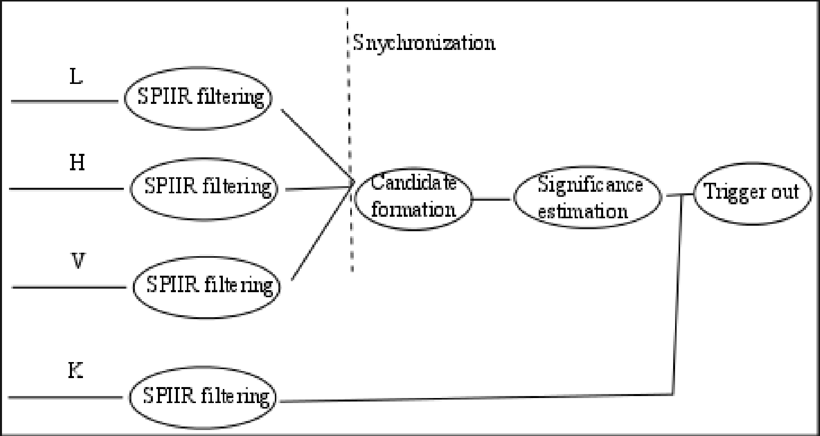
$$\frac{4^3}{3^3} = \frac{64}{27} \approx 2.37$$

Future Work

Pipeline Structure



Pipeline Structure



Algorithms

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and $P = \max\{S, T\}$.

$$\frac{4^2}{3^2} = \frac{16}{9} \approx 1.78$$

Questions?